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(54) **SUBSTRATE PROCESSING APPARATUS**

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(51) **Int. Cl.**

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C23F 1/00	(2006.01)
H01L 21/306	(2006.01)
C23C 16/06	(2006.01)
C23C 16/22	(2006.01)

(52) **U.S. Cl.** **118/724**; 156/345.33; 156/345.37

(58) **Field of Classification Search** 118/724; 156/345.33, 345.37

See application file for complete search history.

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(57) **ABSTRACT**

A substrate processing apparatus in accordance with the present invention includes a process chamber configured to accommodate a substrate, a gas supply line configured to supply a gas to an inside of the process chamber, and an exhaust line configured to exhaust the inside of the process chamber. The gas supply line of the substrate processing apparatus includes a preheating unit preheating the gas supplied from a gas source, a metal pipeline having an angled section wherein the metal pipe line connects the preheating unit and the inside of the process chamber to supply the gas preheated by the preheating unit into the process chamber, and a heat dissipation member covering the angled section to dissipate heat from the angled section.

6 Claims, 6 Drawing Sheets

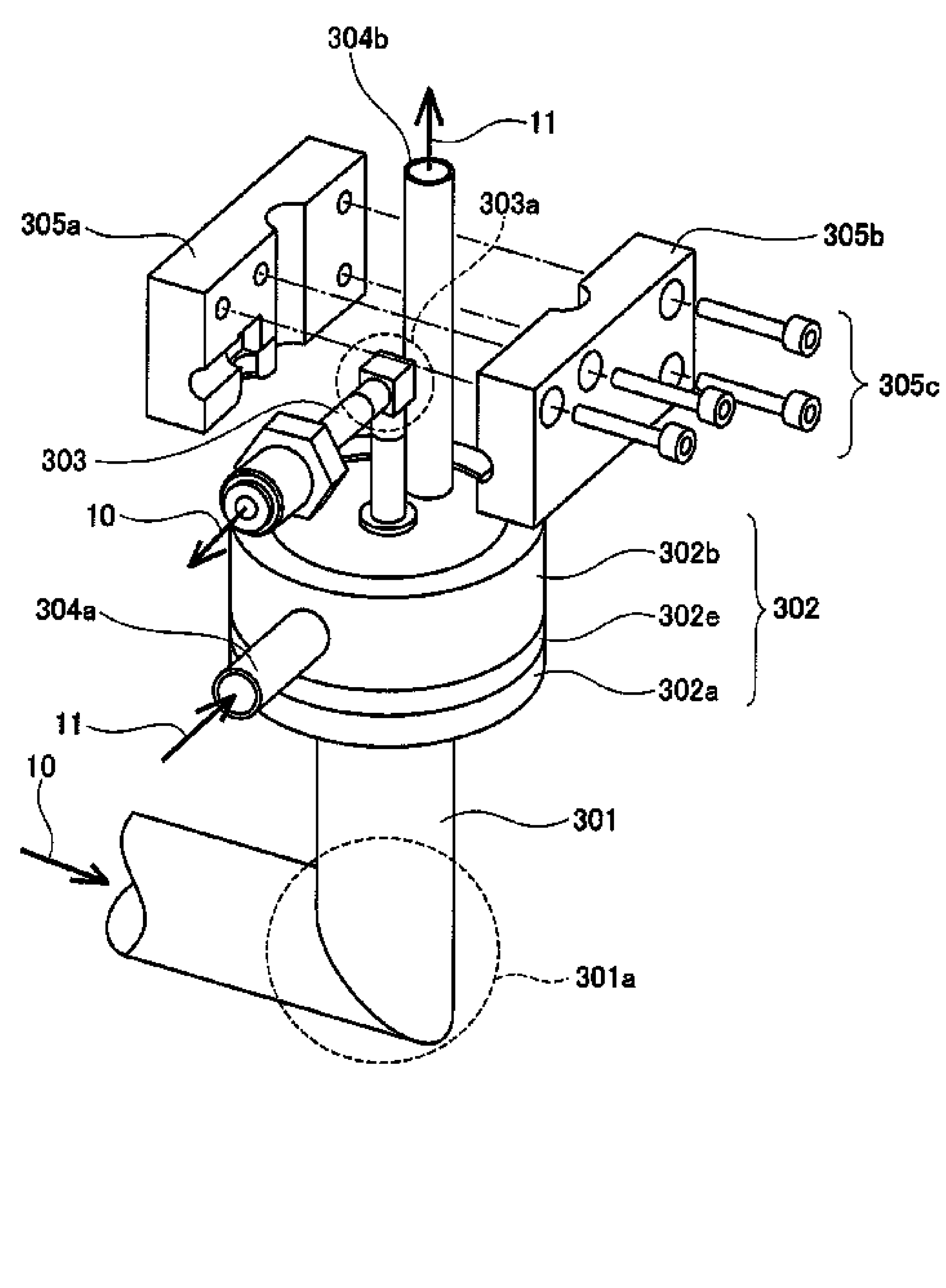
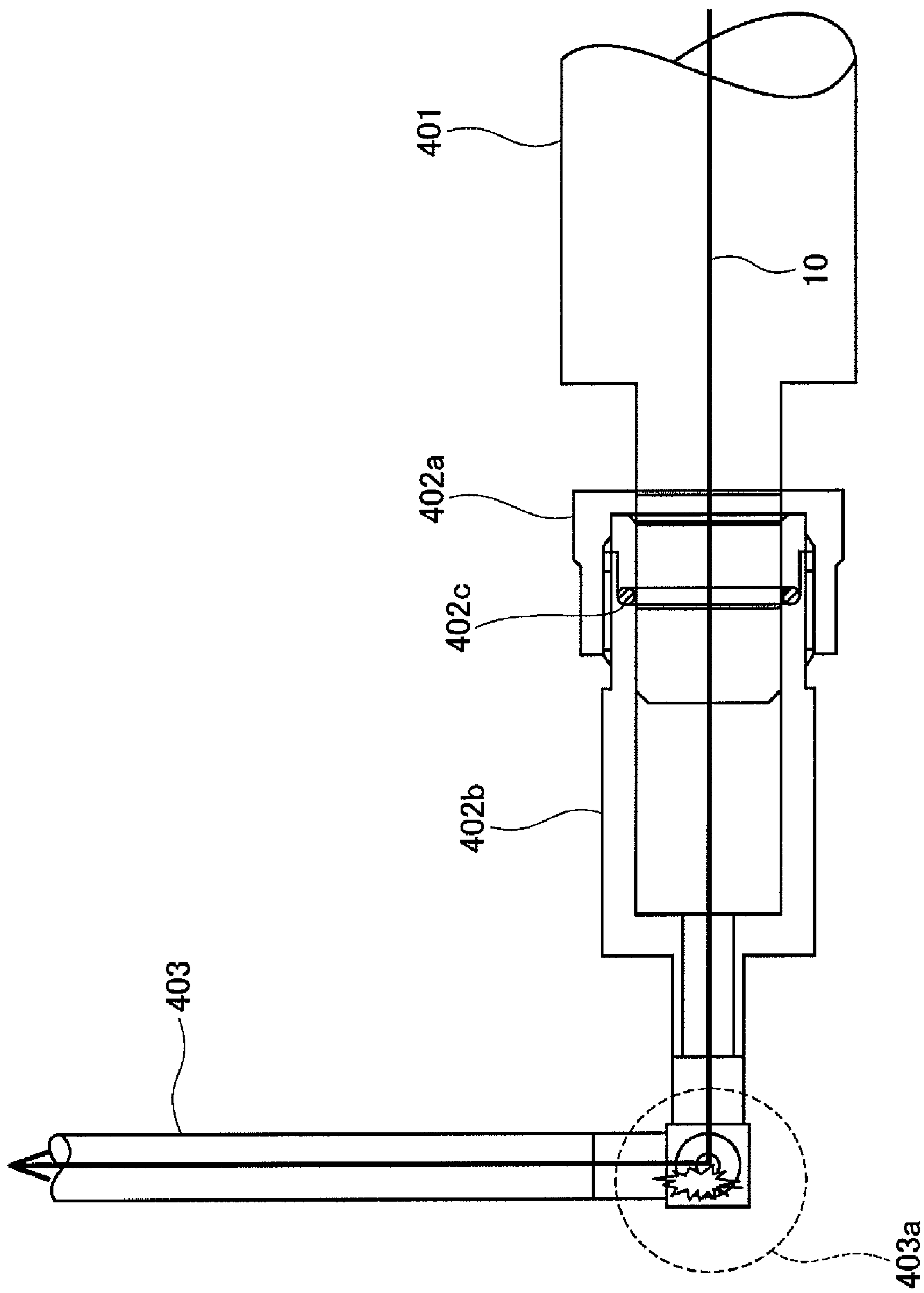
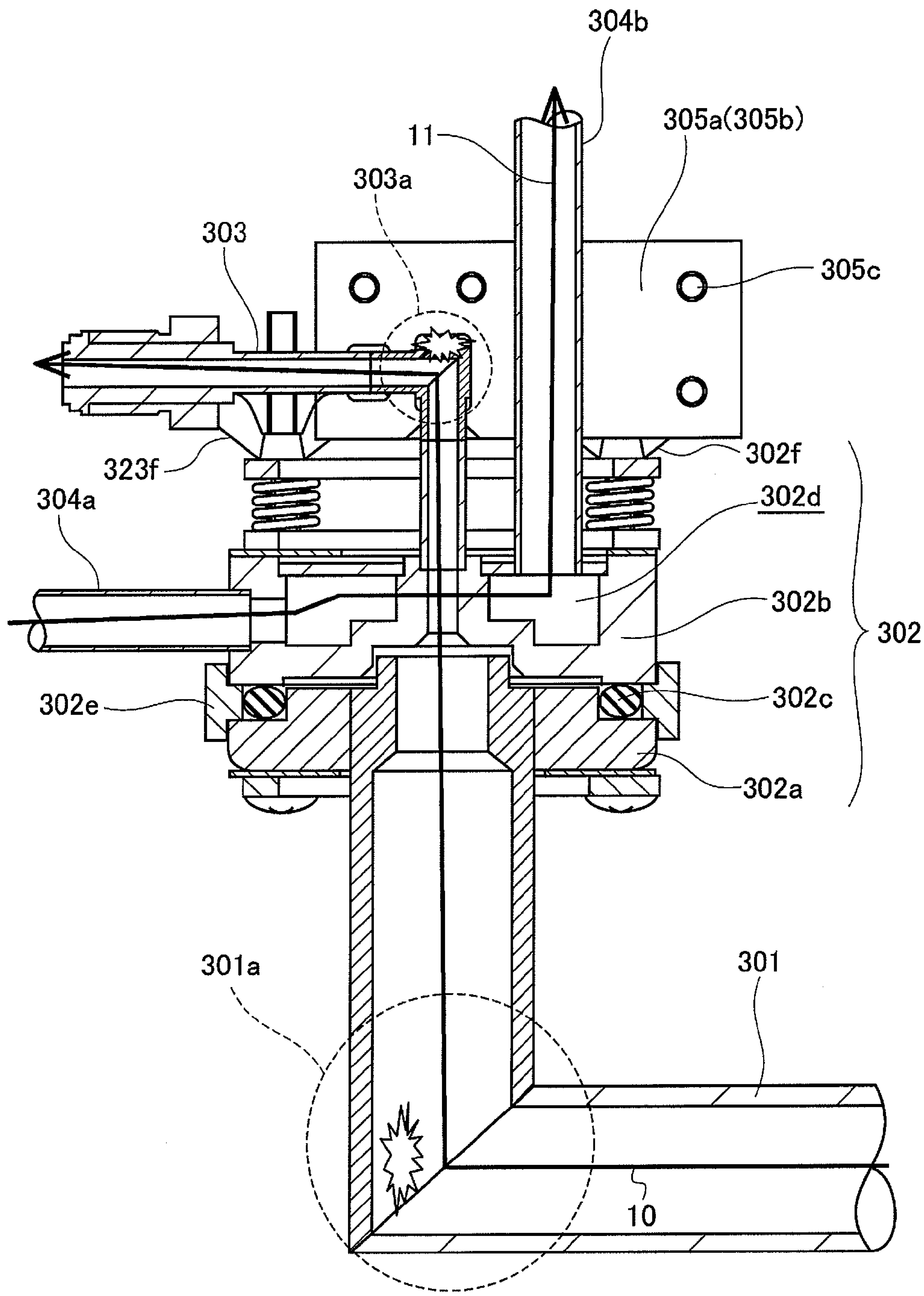


Fig. 1



<Prior Art>

Fig. 2



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11
305a(305b)
303a
303
305c
323f
302f
304a
302d
302b
302
302e
302c
302a
301a
301
10

Fig. 3

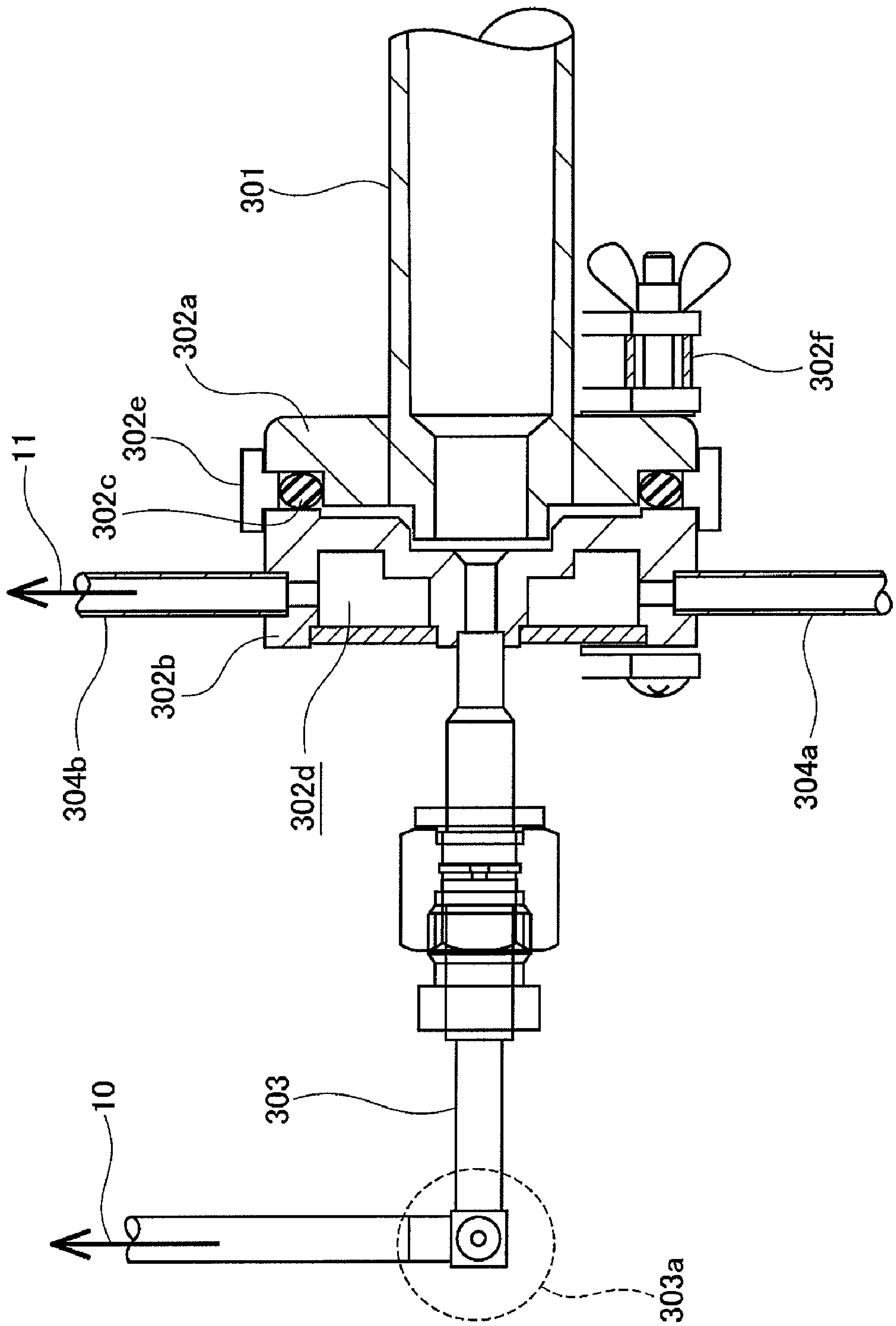
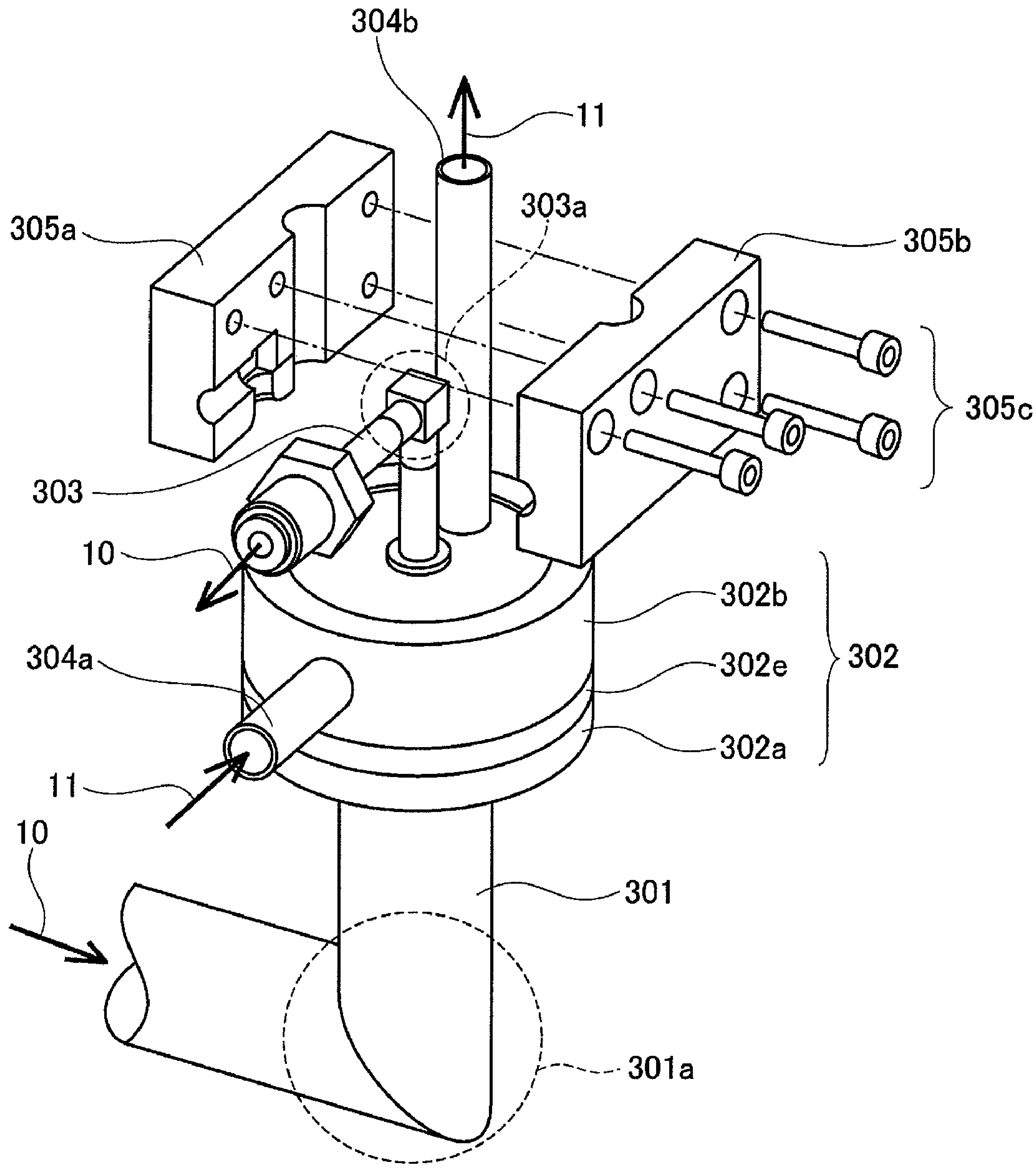


Fig. 4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302b
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302e
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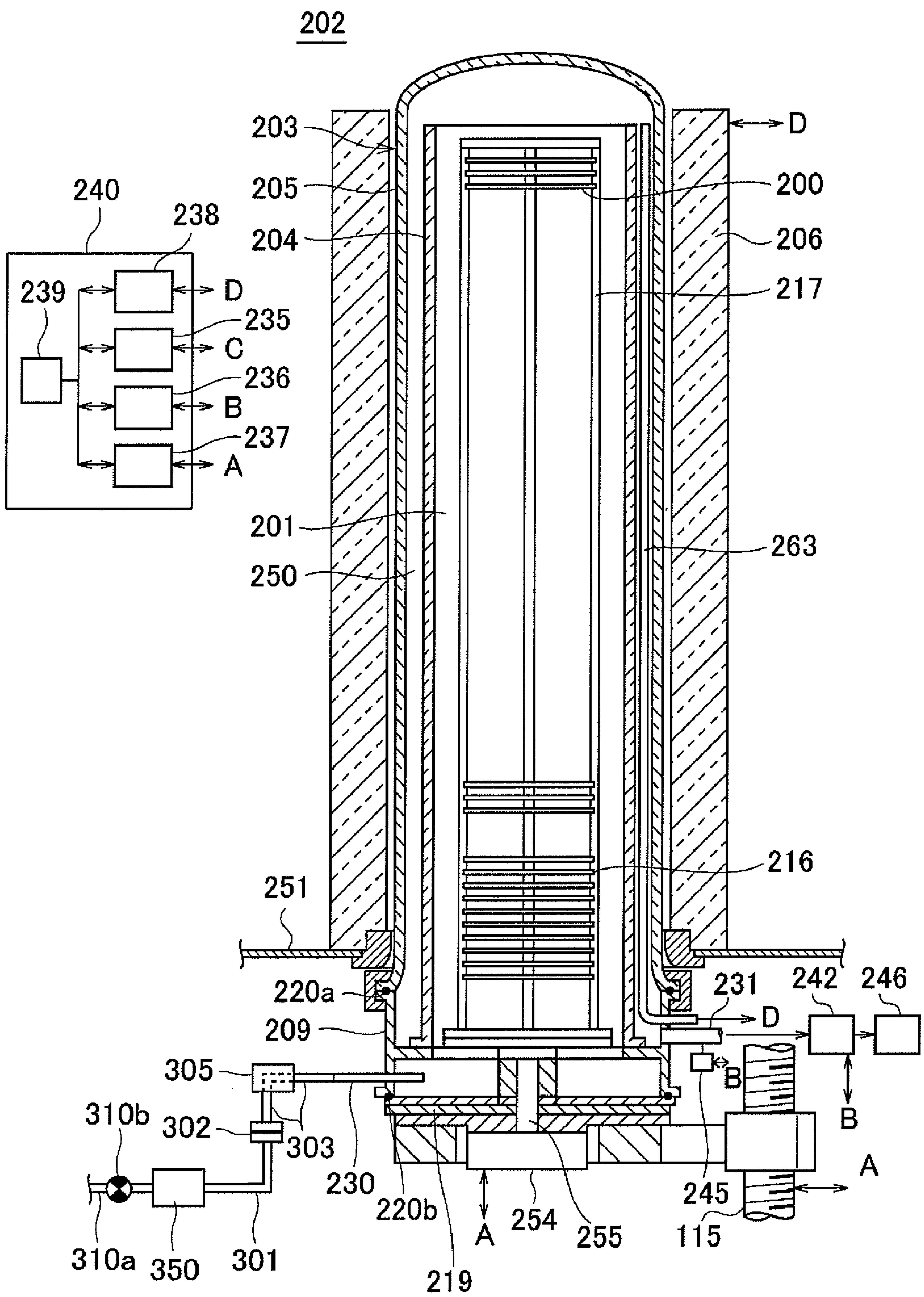
11
10
301
301a

Fig. 5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D
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C
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B
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A
200
206
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216
251
220a
209
231
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310b
302
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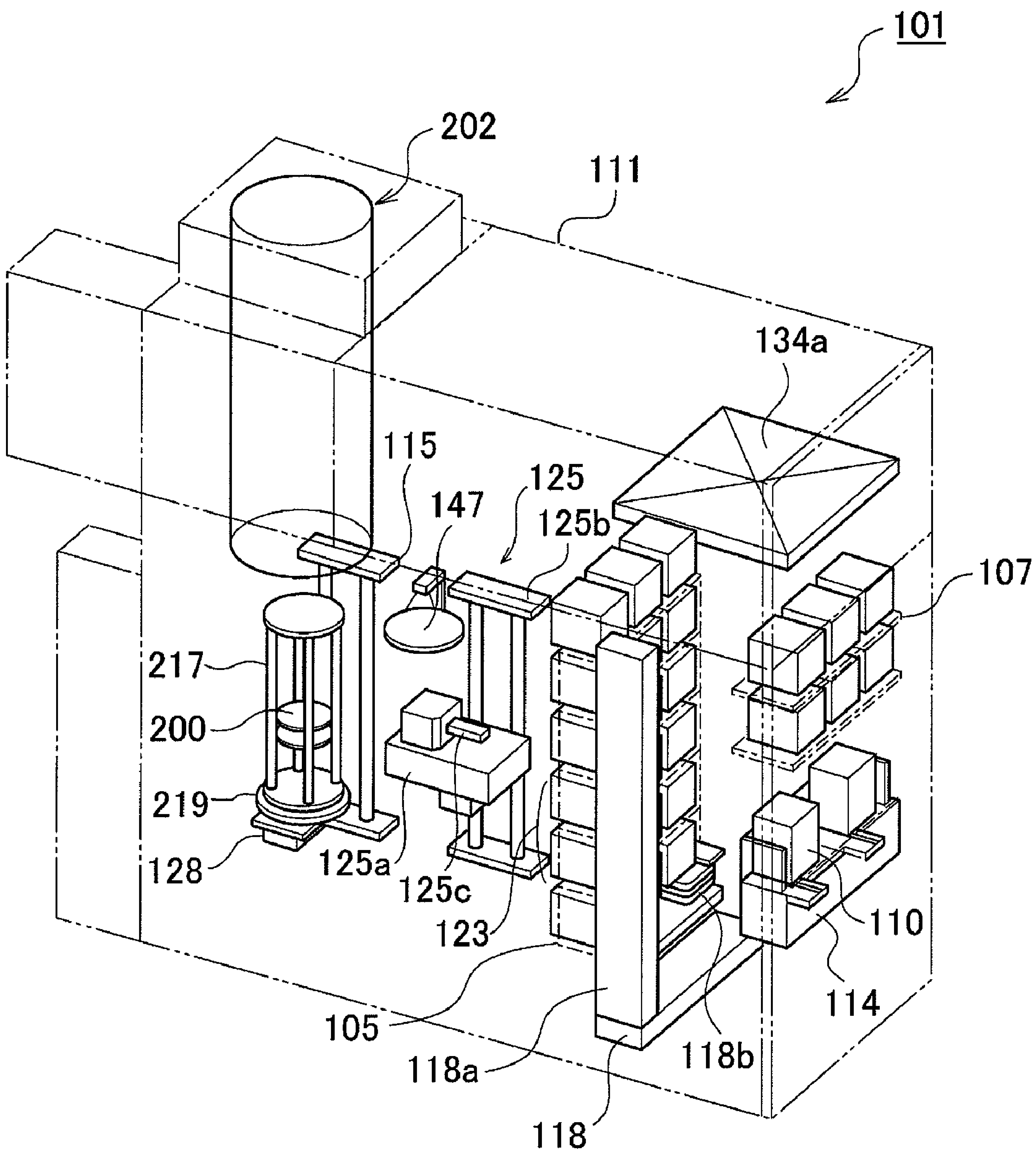
230
220b
310a
350
301
219
254
255
245
115

Fig. 6


101
202
111
134a
115
125
147
125b
107
217
200
219
128
125a
125c
123
110
105
114
118a
118b
118

SUBSTRATE PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED PATENT APPLICATION

This U.S. non-provisional patent application claims priority under 35 U.S.C. §119 of Japanese Patent Application No. 2008-194743, filed on Jul. 29, 2008, in the Japanese Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a substrate processing apparatus for processing a substrate.

2. Description of the Prior Art

Conventionally, a substrate processing apparatus includes a process chamber that receives a substrate, a gas supply line that supplies gas into the process chamber, and an exhaust line that exhausts gas from the process chamber. The substrate is loaded into the process chamber, and the gas is supplied into the process chamber and exhausted from the process chamber. In this way, the substrate is processed while supplying the gas to the substrate. For several kinds of gas, gas may be preheated prior to its supply into the process chamber in order to increase a gas reaction speed (for example, see Patent Document 1).

[Patent Document] Patent Publication No. H5-295549

However, if the gas supplied into the process chamber is preheated by a preheating unit, metal contamination may occur in the substrate or the process chamber.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a substrate processing apparatus which is capable of suppressing the occurrence of metal contamination in a substrate or a process chamber when gas supplied into the process chamber is preheated by a preheating unit.

According to an aspect of the present invention, there is provided a substrate processing apparatus, including: a process chamber configured to accommodate a substrate; a gas supply line configured to supply a gas to an inside of the process chamber; and an exhaust line configured to exhaust the inside of the process chamber, wherein the gas supply line includes: a preheating unit preheating the gas supplied from a gas source; a metal pipeline having an angled section, the metal pipe line connecting the preheating unit and the inside of the process chamber to supply the gas preheated by the preheating unit into the process chamber; and a heat dissipation member covering the angled section to dissipate heat from the angled section, the heat dissipation member including a pair of metal members facing each other to cover an outer surface of the angled section and a clamping means to fasten the pair of metal members to each other.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view illustrating a structure of a gas supply line in a conventional substrate processing apparatus.

FIG. **2** is a sectional view illustrating a structure of a gas supply line in a substrate processing apparatus relevant to one embodiment of the present invention.

FIG. **3** is a sectional view illustrating a structure of a gas supply line in a substrate processing apparatus relevant to another embodiment of the present invention.

FIG. **4** is a perspective view illustrating a gas supply line in a substrate processing apparatus relevant to one embodiment of the present invention.

FIG. **5** is a sectional view illustrating a process furnace in a substrate processing apparatus relevant to one embodiment of the present invention.

FIG. **6** is a schematic view illustrating a structure of a substrate processing apparatus relevant to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The inventors have made intensive studies on the cause of the above-described metal contamination. As a result, the inventors found out that temperature rose locally in a bent section of a metal pipeline configured to supply preheated gas into a process chamber, and such a temperature rise was one cause of metal contamination.

That is, the inventors found out that, if the bent section existed in the metal pipeline, heated gas collided against a metal pipeline inner wall constituting the bent section, temperature of the bent section rose locally, metal component was desorbed from the metal pipeline, the desorbed metal component flowed into the process chamber together with the gas, and thus, metal contamination occurred in the substrate or the process chamber. Hence, the inventors obtained the knowledge that the local temperature rise of the bent section could be suppressed and the occurrence of metal contamination could be suppressed by installing a heat dissipation member to cover an outer periphery of the bent section formed in the metal pipeline. The present invention was invented based on this knowledge.

Hereinafter, explanation will be given on one embodiment of the present invention with reference to drawings.

FIG. **2** is a sectional view illustrating a structure of a gas supply line in a substrate processing apparatus relevant to one embodiment of the present invention. FIG. **4** is a perspective view illustrating a gas supply line in a substrate processing apparatus relevant to one embodiment of the present invention. FIG. **5** is a sectional view illustrating a process furnace in a substrate processing apparatus relevant to one embodiment of the present invention. FIG. **6** is a schematic view illustrating a structure of a substrate processing apparatus relevant to one embodiment of the present invention.

(1) Structure of Substrate Processing Apparatus

First, an exemplary structure of a substrate processing apparatus **101** relevant to one embodiment of the present invention will be described with reference to FIG. **6**. The substrate processing apparatus **101** relevant to the current embodiment is configured as, for example, a vertical type nitriding treatment apparatus.

As shown in FIG. **6**, the substrate processing apparatus **101** relevant to the current embodiment includes a housing **111**. To carry in and carry out wafers (substrate) **200** made of silicon, a cassette **110** is used as a wafer carrier (substrate container) accommodating a plurality of wafers **200**. At the inner forward side o the housing **111** (the right side of FIG. **6**), a cassette stage (substrate container table) **114** is installed. The cassette **110** is designed to be carried in on the cassette stage **114**, and to be carried from the cassette stage **114** out of the housing **111**, by an in-plant carrying device (not shown).

By the in-plant carrying device, the cassette **110** is installed on the cassette stage **114** so that the wafers **200** maintain a vertical position inside the cassette **110**, and a wafer carrying-in and carrying-out opening of the cassette **110** faces an upward direction. The cassette stage **114** is configured so that the cassette **110** is rotated 90 degrees in a longitudinal direction to face the backward of the housing **111**, and the wafers **200** inside the cassette **110** take a horizontal position, and the wafer carrying-in and carrying-out opening of the cassette **110** faces the backward of the housing **111**.

Near to the center part inside the housing **111** in a front and back direction, a cassette shelf (substrate container placement shelf) **105** is installed to store a plurality of cassettes **110** in a plurality of stages and a plurality of rows. At the cassette shelf **105**, a transfer shelf **123** is installed to store the cassettes **110** which are carrying objects of a wafer transfer mechanism **125** to be described later. At the upward of the cassette stage **114**, a standby cassette shelf **107** is installed to store a standby cassette **110**.

Between the cassette stage **114** and the cassette shelf **105**, a cassette carrying device (substrate container carrying device) **118** is installed. The cassette carrying device **118** includes a cassette elevator (substrate container elevating mechanism) **118***a*, which is capable of holding and moving the cassette **110** upward and downward, and a cassette carrying mechanism (substrate container carrying mechanism) **118***b* as a carrying mechanism, which is capable of holding and moving the cassette **110** horizontally. The cassette carrying device **118** is designed to carry the cassette **110** among the cassette stage **114**, the cassette shelf **105**, the standby cassette shelf **107**, and the transfer shelf **123** by continuous motions of the cassette elevator **118***a* and the cassette transfer mechanism **118***b*.

At the backward of the cassette shelf **105**, a wafer transfer mechanism (substrate transfer mechanism) **125** is installed. The wafer transfer mechanism **125** includes a wafer transfer device (substrate transfer device) **125***a*, which is capable of horizontally rotating or straightly moving the wafer **200**, and a wafer transfer device elevator (substrate transfer device elevating mechanism) **125***b* configured to move the wafer transfer device **125***a* upward and downward. The wafer transfer device **125***a* includes tweezers (jig for substrate transfer) **125***c* for holding the wafer **200** at a horizontal position. By the continuous operation of the wafer transfer device **125***a* and the wafer transfer device elevator **125***b*, the wafer transfer mechanism **125** is configured to pick up the wafer **200** into the cassette **110** on the transfer shelf **123** and charge the wafer **200** into a boat (substrate holding member) **217** to be described later, or to discharge the wafer **200** from the boat **217** and accommodate the wafer **200** in the cassette **110** on the transfer shelf **123**.

At the upward of the rear part of the housing **111**, a process furnace **202** is installed, and the lower end part of the process furnace **202** is configured to be opened and closed by a furnace throat shutter (furnace throat opening/closing mechanism) **147**. The structure of the process furnace **202** will be described later.

At the downward of the process furnace **202**, a boat elevator (substrate support member elevating mechanism) **115** is installed as an elevating mechanism to carry the boat **217** inside or outside the process furnace **202**. As a connector, an arm **128** is installed at the elevating table of the boat elevator **115**. On the arm **128**, a seal cap **219** is configured to vertically support the boat **217**, and horizontally installed as a lid to air-tightly close the lower part of the process furnace **202** when the boat **217** is moved upward by the boat elevator **115**.

The boat **217** is installed with a plurality of holding members, and is configured to horizontally hold a plurality of sheets (for example, from about 50 to 150 sheets) of wafers **200** in a state of being vertically arranged, with their centers aligned. A detailed structure of the boat **217** will be described later.

At the upward of the cassette shelf **105**, a clean unit **134***a* configured by a supply fan and a dust-proof filter is installed. The clean unit **134***a* is configured to circulate purified clean air through the inside of the housing **111**.

Also, at the left end part of the housing **111**, which is an opposite part to the wafer transfer device elevator **125***b* and the boat elevator **115**, a clean unit (not shown) is installed to supply clean air. The clean air unit is also configured by a supply fan and a dust-proof filter. The clean air blown from the clean unit (not shown) flows through the surrounding area of the wafer transfer device **125***a* and the boat **217**, and then is exhausted to the outside of the housing **111** by an exhaust device (not shown).

(2) Operation of Substrate Processing Apparatus

Next, explanation will be given on the operation of the substrate processing apparatus **101** relevant to the current embodiment.

First, the cassette **110** is placed on the cassette stage **114** by the in-plant carrying device (not shown) such that the wafer **200** is held at a vertical position and the wafer carrying-in and carrying-out opening of the cassette **110** faces an upward direction. Thereafter, by the cassette stage **114**, the cassette **110** is rotated 90 degrees in a longitudinal direction to face the backward of the housing **111**. As a result, the wafer **200** inside the cassette **110** takes a horizontal position, and the wafer carrying-in and carrying-out opening of the cassette **110** faces the backward of the housing **111**.

Then, the cassette **110** is automatically carried and temporarily stored in a specific shelf position of the cassette shelf **105** or the standby cassette shelf **107** by the cassette carrying device **118**, and transferred from the cassette shelf **105** or the standby cassette shelf **107** to the transfer shelf **123** by the cassette carrying unit **118**, or directly transferred to the transfer shelf **123**.

When the cassette **110** is delivered to the transfer shelf **123**, the wafer **200** is picked up from the cassette **110** through the wafer carrying-in and carrying-out opening by the tweezers **125***c* of the wafer transfer device **125***a*, and is charged into the boat **217** disposed at the backward of the transfer chamber **124** by the continuous operation of the wafer transfer device **125***a* and the wafer transfer device elevator **125***b*. The wafer transfer mechanism **125**, which delivers the wafer **200** to the boat **217**, returns to the cassette **110** and charges the next wafer **200** into the boat **217**.

When predetermined sheets of the wafers **200** are charged into the boat **217**, the lower end part of the process furnace **202**, which was kept closed by the furnace throat shutter **147**, is opened by the furnace throat shutter **147**. Subsequently, the seal cap **219** is moved upward by the boat elevator **115**, and the boat **217** holding a group of wafers **200** is loaded into the process furnace **202**. After the loading, an optional processing is applied to the wafers **200** in the process furnace **202**. After the processing, the wafers **200** and the cassette **110** are unloaded from the housing **111** in a reverse sequence of the above.

(3) Structure of Process Furnace

A structure of the process furnace **202** relevant to the current embodiment will be described below with reference to FIG. **2**, FIG. **4** and FIG. **5**. FIG. **5** is a vertical sectional view illustrating the process furnace **202** of the substrate processing apparatus relevant to one embodiment of the present invention.

(Process Chamber)

As illustrated in FIG. **5**, the process chamber **202** includes a process tube as a reaction tube. The process tube **203** includes an inner tube **204** as an inner reaction tube, and an outer tube **205** as an outer reaction tube installed outside the inner tube **204**. The inner tube **204** is made of a heat-resistant material, for example, quartz (SiO_2) or silicon carbide (SiC), and is formed in a cylindrical shape with an upper part and a lower part opened. At the cylindrical hollow part of the inner tube **204**, a process chamber **201** where wafers **200** such as substrates are processed is formed. The inside of the process chamber **201** is configured to receive the boat **217** which will be described later. The outer tube **205** is installed concentrically with the inner tube **204**. An inner diameter of the outer tube **205** is greater than an outer diameter of the inner tube **204**, and the outer tube **205** is formed in a cylindrical shape with an upper part closed and a lower part opened. The outer tube **205** is made of a heat-resistant material, for example, quartz or silicon carbide.

At the downward of the outer tube **205**, a manifold **209** is installed concentrically with the outer tube **205**. The manifold **209** is made of stainless steel or the like and is formed in a cylindrical shape with an upper part and a lower part opened. The manifold **209** connects and supports the lower end part of the inner tube **204** and the lower end part of the outer tube **205**. Between the manifold **209** and the outer tube **205**, an O-ring **220***a* is installed as a sealing member. Since the manifold **209** is supported on a heat base **251**, the process tube **203** is kept in a vertically fixed state. A reaction vessel is formed by the process tube **203** and the manifold **209**.

(Gas Supply Line)

As illustrated in FIG. **2**, at the manifold **209**, a nozzle **230** as a gas inlet port is connected vertically to communicate with the inside of the process chamber **201**. At the upstream end of the nozzle **230**, the downstream end of a metal pipeline **303** made of a metal is connected. The upstream end of the metal pipeline **303** is connected to the downstream end of a quartz pipeline **301** via a joint **302**. The upstream end of the quartz pipeline **301** is connected to a preheating unit **350**. The preheating unit **350** is configured to supply gas such as N_2O gas from a gas supply source (not shown) through a gas supply pipe **310***a*. At the gas supply pipe **310***a*, an open-close valve **310***b* is installed.

When the open-close valve **310***b* is opened, gas is supplied from the gas supply source (not shown) into the preheating unit **350**, and is heated by the preheating unit **350**. The high-temperature gas heated by the preheating unit **350** is supplied into the process chamber **201** through the quartz pipeline **301**, the metal pipeline **303**, and the nozzle **230**. Mainly, a gas supply line for supplying gas into the process chamber **201** is configured by the nozzle **230**, the metal pipeline **303**, the joint **302**, the quartz pipeline **301**, the preheating unit **350**, and the gas supply source (not shown).

As illustrated in FIG. **2** and FIG. **4**, a bent section **303***a* is formed at the metal pipeline **303**. Also, at the metal pipeline **303**, a heat dissipation member **305** is installed to cover the outer periphery of the bent section **303***a*.

The heat dissipation member **305** includes a pair of metal members **305***a* and **305***b* configured so that the outer periphery of the bent section **303***a* formed in the metal pipeline **303** is intervened between them, and a clamp **305***c* configured to fix the metal member **305***a* and the metal member **305***b* The facing surfaces of the pair of the metal members **305***a* and **305***b* are recessed in the same shape as the outline of the bent section **303***a* in order to improve the heat dissipation efficiency of the bent section **303***a* due to heat transfer by increasing a contact area between the outer periphery of the bent section **303***a* and the metal members **305***a* and **305***b*. Also, it is preferable that the pair of the metal members **305***a* and **305***b* is made of a metal having high heat dissipation characteristic due to a heat transfer rate or radiation, and, for example, a metal such as aluminum or copper may be used.

Moreover, at the pair of the metal members **305***a* and **305***b*, a groove structure (heat sink structure) for increasing a surface area may be formed. The bent section **303***a* is not limited to the current embodiment in which the bent section **303***a* is bent at 90° (the bent section **303***a* is formed in an elbow shape), and, for example, may be bent at 40° or 60°.

As illustrated in FIG. **2**, the joint **302** includes a first flange **302***a* installed in the downstream end of the quartz pipeline **301**, and a second flange **302***b* installed in the upstream end of the metal pipeline **303**. Since the first flange **302***a* and the second flange **302***b* are joined to face each other through the O-ring **302***c* as the sealing member by the clamp **302***f*, the downstream of the quartz pipeline **301** and the upstream of the metal pipeline **303** are air-tightly connected. Also, between the first flange **302***a* and the second flange **302***b*, a Teflon ring **302***e* is installed to surround the outer periphery of the O-ring **302***c*. An inner diameter of the O-ring **302***c* as the sealing member is greater than an inner diameter of the quartz pipeline **301** and an inner diameter of the metal pipeline **303** so that the high-temperature gas flow **10** flowing from the quartz pipeline **301** to the metal pipeline **303** does not directly contact the O-ring **302***c*.

As illustrated in FIG. **2**, at the inside of the second flange **302***b*, a cooling medium flow channel **302***d* is formed to circulate cooling liquid or cooling gas. The second flange **302***b* is connected to a cooling medium supply pipe **304***a*, which is configured to supply cooling liquid or cooling gas as a cooling medium into the cooling medium flow channel **302***d*, and a cooling medium exhaust pipe **304***b*, which is configured to exhaust the cooling liquid or the cooling gas from the inside of the cooling medium flow channel **302***d*. The cooling medium exhaust pipe **304***b* contacts the heat dissipation member **305** so that heat transfer to the heat dissipation member **305** is possible. Specifically, the cooling medium exhaust pipe **304***b* is intervened between the pair of the metal members **305***a* and **305***b*, together with the metal pipeline **303**. The facing surfaces of the pair of the metal members **305***a* and **305***b* are recessed in the same shape as the outline of the cooling medium exhaust pipe **304***b* in order to improve the heat dissipation efficiency of the metal members **305***a* and **305***b* due to heat transfer by increasing a contact area between the cooling medium exhaust pipe **304***b* and the metal members **305***a* and **305***b*. Also, instead of the cooling medium exhaust pipe **304***b*, the cooling medium supply pipe **304***a* may be intervened between the pair of the metal members **305***a* and **305***b*.

As illustrated in FIG. **2**, near to the downstream end of the quartz pipeline **301** (upstream side of the quartz pipeline **301** near to the joint **302**), a bent section **301***a* is installed so as to accelerate collision of heated gas against the quartz pipeline **301** (heat dissipation by collision). However, the quartz pipeline **301** relevant to the present invention is not limited to the above-described shape, and the bent section **301***a* may not be installed as illustrated in FIG. **3**.

(Exhaust Line)

At the manifold **209**, an exhaust pipe **231** is installed to exhaust atmosphere inside the process chamber **201**. The exhaust pipe **231** communicates with a lower end of a cylindrical space **250** formed by a gap between the inner tube **204** and the outer tube **205**. At the downstream side of the exhaust pipe **231** (opposite to the contact side with the manifold **209**), a pressure sensor **245** as a pressure detector, an Auto Pressure Controller (APC) valve **242** as a pressure controller, and a vacuum pump **246** as a vacuum exhaust device are connected sequentially from the upstream side. Mainly, an exhaust line configured to exhaust the inside of the process chamber **201** is configured by the exhaust pipe **231**, the pressure sensor **245**, the APC valve **242**, and the vacuum pump **246**. At the APC valve **242** and the pressure sensor **245**, a pressure control unit **236** is electrically connected. The pressure control unit **236** is configured to control the APC valve **242** so that pressure inside the process chamber **201** is made to have a desired level at a desired timing, based on a pressure value detected by the pressure sensor **245**.

(Seal Cap)

At the lower part of the manifold **209**, a seal cap **219** is installed as a furnace throat cap body that can air-tightly close the lower opening of the manifold **209**. The seal cap **219** contacts the lower end of the manifold **209** from a vertical-direction lower side. The seal cap **219** is made of stainless steel or the like and is formed in a disk shape. At the surface of the seal cap **219**, an O-ring **220***b* is installed as a sealing member which contacts the lower end of the manifold **209**. At the opposite side to the process chamber **201** which is near to the center part of the seal cap **219**, a rotating mechanism **254** is installed to rotate a boat. A rotation shaft **255** of the rotating mechanism **254** passes through the seal cap **219** and supports the boat **217** from the downward.

The rotating mechanism **254** is configured to rotate the boat **217** so that the wafer **200** is rotatable. The seal cap **219** is configured to move upward and downward by a boat elevator **115** as an elevating mechanism installed vertically in the outside of the process tube **203**. The boat elevator **115** is configured to move the seal cap **219** upward so that the boat **217** is carried in and out of the process chamber **201**. At the rotating mechanism **254** and the boat elevator **115**, a driving control unit **237** is electrically connected. The driving control unit **237** is configured to control the rotating mechanism **254** and the boat elevator **115** so that they are operated at a desired timing.

(Boat)

As described above, the boat **217** as a substrate holder is configured to hold a plurality wafers **200** at a horizontal position in multiple stages, with their centers aligned. The boat **217** is made of a heat-resistant material, for example, quartz or silicon carbide. At the lower part of the boat **217**, a plurality of heat insulation plates **216** as disk-shaped heat insulation members made of a heat-resistant material such as quartz or silicon carbide are arranged at a horizontal position in multiple stages and are configured to make it difficult to transfer heat from the heater **206** toward the manifold **209**.

(Heating Unit)

At the outside of the process tube **203**, the heater **206** is installed as a heating unit to surround the sidewall surface of the process tube **203**. The heater **206** has a cylindrical shape and is installed vertically so that it is supported by a heater base **251** as a holding plate.

At the inside of the process tube **203**, a temperature sensor **263** is installed as a temperature detector. A temperature control unit **238** is electrically connected to the heater **206** and the temperature sensor **263**. The temperature control unit **238** is configured to control an electrified state of the heater **206**, based on temperature information detected by the temperature sensor **263**, so that temperature inside the process chamber **201** is made to have a desired temperature distribution at a desired timing.

(Controller)

A gas flow rate control unit **235**, a pressure control unit **236**, a driving control unit **237**, and a temperature control unit **238** are electrically connected to a main control unit **239** which controls an overall operation of the substrate processing apparatus **100** (hereinafter, the gas flow rate control unit **235**, the pressure control unit **236**, the driving control unit **237**, and the temperature control unit **238** will be referred to as an I/O control unit). The gas flow rate control unit **235**, the pressure control unit **236**, the driving control unit **237**, the temperature control unit **238**, and the main control unit **239** constitute a controller **240** as a control unit.

(4) Operation of Process Furnace

Next, explanation will be given on a method for forming a nitride film such as a silicon nitride film, which is one of semiconductor device manufacturing processes, wherein the nitride film such as a silicon nitride film is formed by supplying NO gas onto a wafer **200** made of silicon or the like by using the process furnace **202** having the above-described structure. In the following description, the operations of the respective parts constituting the substrate processing apparatus **101** are controlled by the controller **240**.

(Substrate Loading Process (S**1**))

First, a plurality of wafers **200** to be processed are charged into the boat **217**. The seal cap **219** is moved downward by the boat elevator **115** and thus the lower end of the manifold **209** is opened. Hence, the boat **217** supporting the plurality of wafers **200** is moved upward by the boat elevator **115** and is loaded into the process chamber **201**. The lower opening (furnace throat) of the manifold **209** is sealed via the O-ring **220***b* by the seal cap **219**. The resulting state is illustrated in FIG. **2**.

(Depressurization Process and Temperature Rising Process (S**2**))

Subsequently, the vacuum pump **246** operates to open the APC valve **242** and evacuate the inside of the process chamber **201** through the exhaust pipe **231**. In this case, the opening degree of the APC valve **242** is feedback controlled, based on the measured value of the pressure sensor **245**, so that the inside of the process chamber **201** is made to have a desired pressure (vacuum degree). Also, the heater **206** is electrified to heat the inside of the process chamber **201**. At this point, the electrified amount of the heater **206** is controlled, based on the measured value of the temperature sensor **263**, so that the surface of the wafer **200** is made to have a desired temperature. The rotating mechanism **254** operates to rotate the wafer **200** together with the boat **217**.

(Gas Supply Process (S**3**))

Subsequently, the open-close valve **310***b* is opened to supply N_2O gas from the gas supply source (not shown) to the preheating unit **350**, and the N_2O gas is heated and decomposed by the preheating unit **350** to generate NO gas. Hence, the generated high-temperature NO gas (or mixed gas of N_2O gas and NO gas) is supplied from the preheating unit **350** to the inside of the process chamber **201** via the quartz pipeline **301**, the metal pipeline **303**, and the nozzle **230**. When the generated NO gas is supplied into the process chamber **201**, the generated NO gas is not returned to N_2O gas and is in a stable state as it is, even though temperature is lowered. It is preferable that the temperature of the N_2O gas heated by the preheating unit **350** is a temperature at which the N_2O gas is decomposed most efficiently, and the related temperature can be obtained experimentally.

The NO gas supplied into the process chamber **201** moves upward at the inside of the process chamber **201**, circulates from the upper opening of the inner tube **204** toward the cylindrical space **250**, and is exhausted from the gas exhaust line. At this point, the NO gas is supplied to the surface of each wafer **200**, and a silicon nitride film (SiN film) is formed on the surface of each wafer **200**.

In the gas supply process (S**3**), cooling liquid or cooling gas as a cooling medium is supplied into the cooling medium flow channel **302***d* formed inside the second flange **302***d*.

(Pressure Rising Process (S**5**))

When the silicon nitride film is formed on the wafer **200** to a desired thickness by continuously supplying the NO gas into the process chamber **201** for a certain time, the open-close valve **310***b* is closed to stop the supply of the NO gas into the process chamber **201**, and gas remaining in the process chamber **201** is exhausted. At this time, by supplying inert gas such as N_2 gas into the process chamber **201** through an inert gas supply line (not shown), the exhaust of the NO gas from the inside of the process chamber **201** can be accelerated. Thereafter, by adjusting the opening degree of the APC valve **242** while continuously supplying the inert gas into the process chamber **201**, pressure inside the process chamber **201** rises up to atmospheric pressure.

(Substrate Discharging Process (S**6**))

Subsequently, by moving the seal cap **219** downward by the boat elevator **115**, the lower end of the manifold **209** is opened and simultaneously the boat **217** holding the processed wafer **200** is moved downward, so that the boat is unloaded from the process chamber **201** (boat unloading). In this way, the processed wafer **200** is discharged from the unloaded boat **217**, and the substrate processing process relevant to the current embodiment is finished.

(5) Effect Relevant to the Current Embodiment

The current embodiment obtains one or more of the following effects (a)~(h).

(a) In accordance with the current embodiment, at the outer periphery of the bent section **303***a* formed in the metal pipeline **303**, the pair of the metal members **305***a* and **305***b* are installed so that the bent section **303***a* is intervened between them. As a result, the local temperature rise of the bent section **303***a* is suppressed by heat transfer from the bent section **303***a* to the heat dissipation member **305**. That is, in the gas supply process (S**3**), the high-temperature NO gas flowing from the quartz pipeline **301** to the inside of the metal pipeline **303** collides against the inner wall of the metal pipeline **303** constituting the bent section **303***a*, and thus, the temperature of the bent section **303***a* will rise locally. However, by the heat transfer from the bent section **303***a* to the heat dissipation member **305**, metal component is dispatched from the metal pipeline **303**, thereby suppressing the occurrence of metal contamination in the wafer **200** or the process chamber **201**.

(b) In accordance with the current embodiment, by installing the pair of the metal members **305***a* and **305***b*, the local temperature rise of the bent section **303***a* can be suppressed, even though the flow rate of the high-temperature NO gas further increases, or the temperature of the NO gas further increases. That is, while suppressing the occurrence of the metal contamination, the substrate can be processed under more various conditions (for example, a higher flow rate, a higher temperature).

(c) In accordance with the current embodiment, the facing surfaces of the pair of the metal members **305***a* and **305***b* are recessed in the same shape as the bent section **303***a*. As a result, since the contact area between the outer periphery of the bent section **303***a* and the pair of the metal members **305***a* and **305***b* increases, the heat transfer from the bent section **303***a* to the heat dissipation member **305** is accelerated, thereby further suppressing the temperature rise of the bent section **303***a*.

(d) In accordance with the current embodiment, by making the outer periphery of the bent section **303***a* intervened between the pair of the metal members **305***a* and **305***b*, the mechanical strength at the position near the bent section **303***a* is improved. Also, since the facing surfaces of the pair of the metal members **305***a* and **305***b* are recessed in the same shape as the outline of the bent section **303***a*, the mechanical strength at the position near the bent section **303***a* is further improved.

(e) In order to suppress the occurrence of metal contamination caused by the local temperature rise of the metal pipeline **303***a*, the metal pipeline **303** for supplying gas into the process chamber **201** may be modified into a quartz pipeline. However, compared with the metal pipeline, the quartz pipeline is difficult to install and is also expensive. In accordance with the current embodiment, by the simple addition of the heat dissipation member **305** to the bent section **303***a* of the metal pipeline **303**, the occurrence of metal contamination is suppressed at low cost and with ease, without changing the material of the metal pipeline **303** and also changing the installation.

(f) In accordance with the current embodiment, the inner diameter of the O-ring **302***c* installed between the first flange **302***a* and the second flange **302***b* is configured to be greater than the inner diameter of the quartz pipeline **301** and the inner diameter of the metal pipeline **303**. As a result, the high-temperature NO gas flowing from the quartz pipeline **301** to the metal pipeline **303** does not directly contact the O-ring **302***c*, and thus, the temperature rise of the O-ring **302***c* is suppressed. As a result, the degradation of the O-ring **302***c* is suppressed, and the maintenance frequency of the substrate processing substrate **101** is reduced. Moreover, since the desorption of component from the O-ring **302***c* is suppressed, the contamination of the wafer **200** or the process chamber **201** is suppressed.

(g) In accordance with the current embodiment, the cooling medium flow channel **302***d* is formed inside the second flange **302***b*, and the cooling liquid or the cooling gas is supplied into the cooling medium flow channel **302***d* in the gas supply process (S**3**). Accordingly, the temperature rise of the O-ring **302***c* is suppressed, the degradation of the O-ring **302***c* is suppressed, and the maintenance frequency of the substrate processing apparatus **101** is reduced. Moreover, since the cooling of the individual members near the second flange **302***b* is accelerated, the temperature of the NO gas supplied into the metal pipeline **303** is lowered and the local temperature rise of the bent section **303***a* is suppressed.

(h) In accordance with the current embodiment, at the position near the downstream end of the quartz pipeline **301** (upstream side of the quartz pipeline **301** near the joint **302**), the bent section **301***a* is installed. Since such a structure causes the high-temperature NO gas to collide against the sidewall of the quartz pipeline **301** constituting the bent section **301***a*, the heat dissipation from the NO gas to the quartz pipeline **301** is accelerated, and the temperature of the NO gas supplied into the metal pipeline **303** is lowered, thereby suppressing the temperature rise of the bent section **303***a* of the metal pipeline **303**. Even though the temperature of the bent section **301***a* of the metal pipeline **303** becomes locally high by the collision with the NO gas, since the bent section **301***a* is made of quartz, metal component is not desorbed from the quartz pipeline **301** and metal contamination does not occur.

The structure of the gas supply line of the conventional substrate processing apparatus is illustrated in FIG. **1**.

Generally, the gas supply line of the conventional substrate processing apparatus includes a quartz pipeline **401** configured to exhaust heated gas, a metal pipeline **403** configured to supply heated gas into a process chamber, and a joint **402** configured to connect the quartz pipeline **401** to the metal pipeline **403**. The joint **402** includes a first flange **402***a* installed in the downstream end of the quartz pipeline **401**, a second flange **402***b* installed in the upstream end of the metal pipeline **403**, and an O-ring **402***c* configured to air-tightly seal the gap between the first flange **402***a* and the second flange **402***b*.

In the conventional substrate processing apparatus, the heat dissipation member is not installed in the bent section **403***a* which is formed in the metal pipeline **403**. Thus, if heated gas collides against the inner wall of the metal pipeline **403** constituting the bent section **403***a*, temperature of the metal pipeline **403** constituting the bent section **403***a* locally rises so that metal component is desorbed from the metal pipeline **403**, and the desorbed metal component flows into the process chamber together with gas, which causes metal contamination in the substrate or the process chamber.

Furthermore, in the conventional substrate processing apparatus, the inner diameter of the O-ring **402***c* is configured to be substantially identical to the inner diameter of the quartz pipeline **401**. For this reason, the high-temperature NO gas flowing from the quartz pipeline **401** to the metal pipeline **403** directly contacts the O-ring **402***c*, and the heat-resistant limit of the O-ring **402***c* has been often exceeded. Moreover, in the conventional substrate processing apparatus, the cooling medium flow channel is not formed inside the second flange **402***b*, and the cooling medium flows into the second flange **402***b*. Hence, it was difficult to suppress the temperature rise of the O-ring **402***c*.

EMBODIMENTS

Hereinafter, embodiments of the present invention and comparative examples will be described.

Embodiment 1

The same process as the above-described substrate processing was performed by using the above-described substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* were provided and the bent section **301***a* was installed in the position near the downstream end of the quartz pipeline **301**. When the heating temperature of the N_2O gas was 1,000° C.; the flow rate of the N_2O gas was 15 L/min; and the flow rate of the cooling liquid (cooling water) was 1.5 L/min, the surface temperature of the O-ring **302***c* was 168° C. in the gas supply process (S**3**), which was much lower than 327° C., that is, the heat-resistant limit of the O-ring **302***c*.

Embodiment 2

The same process as the above-described substrate processing was performed by using the above-described substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* were provided and the bent section **301***a* was installed in the position near the downstream end of the quartz pipeline **301**. When the heating temperature of the N_2O gas was 1,000° C.; the flow rate of the N_2O gas was 10 L/min; and the flow rate of the cooling liquid (cooling water) was 1.5 L/min, the surface temperature of the bent section **303***a* was suppressed to 155° C. in the gas supply process (S**3**).

Embodiment 3

The same process as the above-described substrate processing was performed by using the above-described substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* were provided and the bent section **301***a* was not installed in the position near the downstream end of the quartz pipeline **301**. When the heating temperature of the N_2O gas was 1,000° C.; the flow rate of the N_2O gas was 10 L/min; and the flow rate of the cooling liquid (cooling water) was 2.5 L/min, the surface temperature of the Teflon ring **302***e* was suppressed to 132° C. in the gas supply process (S**3**).

Embodiment 4

The same process as the above-described substrate processing was performed by using the above-described substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* were provided and the bent section **301***a* was not installed in the position near the downstream end of the quartz pipeline **301**. When the heating temperature of the N_2O gas was 1,000° C.; the flow rate of the N_2O gas was 10 L/min; and the flow rate of the cooling liquid (cooling water) was 2.5 L/min, the surface temperature of the Teflon ring **302***e* was suppressed to 93° C. in the gas supply process (S**3**). That is, by installing the bent section **301***a* at the position near the downstream end of the quartz pipeline **301**, the temperature of gas flowing through the metal pipeline **303** was lowered, and thus, the temperature rise of the bent section **303***a* of the metal pipeline **303** was also suppressed.

Comparative Example 1

The substantially same process as the embodiment 1 was performed by using the conventional substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* was not provided. When the heating temperature of the N_2O gas was 1,000° C. and the flow rate of the N_2O gas was 5 L/min, the surface temperature of the O-ring **402***c* was 335° C. in the gas supply process (S**3**) and also exceeded 327° C. which was the heat-resistant limit of the O-ring **402***c*.

Comparative Example 2

The substantially same process as the embodiment 2 was performed by using the conventional substrate processing apparatus in which the pair of the metal members **305***a* and **305***b* was not provided. When the heating temperature of the N_2O gas was 1,000° C. and the flow rate of the N_2O gas was 10 L/min, the surface temperature of the O-ring **402***c* was 315° C. in the gas supply process (S**3**).

<Another Embodiment of the Present Invention>

Although the case of generating NO gas by supplying N_2O gas into the preheating unit **350** has been described as an example in the above-described embodiments, the present invention is not limited to those embodiments. That is, gases other than the N_2O gas may also be supplied to the preheating unit **350** and heated.

Also, the present invention is not limited to a case of supplying one kind of gas into the process chamber **201**, but may also be more suitably applied to a case of supplying various kinds of gases into the process chamber **201** simultaneously or alternately. In this case, only several kinds of gases may be heated by the preheating unit, and all kinds of gases may be heated by the preheating unit.

Furthermore, the present invention can also be applied to positions other than the bent section **303***a* of the metal pipeline **303**. That is, the present invention can be very suitably applied to positions, except the bent section **303***a*, where temperature may rise locally due to collision of heated gas. For example, in case where high-temperature gas collides against constituent parts such as an open-close valve or vacuum tube installed on the passage of the gas flow **10** and temperatures of those constituent members locally rise, the local temperature rise can be suppressed by intervening those constituent parts between the pair of the metal members **305***a* and **305***b*, thereby suppressing the occurrence of metal contamination.

Although the case of providing the pair of the metal members **305***a* and **305***b* as the heat dissipation member **305** has been described in the above-described embodiments, the present invention is not limited to those embodiments. That is, the heat dissipation member **305** may be configured by one piece of a metal member, or may be configured by three or more pieces of metal members. Furthermore, the present invention is not limited to the case of configuring the heat dissipation member **305** with metal members, the heat dissipation member **305** may also be made of non-metal materials such as ceramic having heat conductivity characteristic.

Although the case where the process tube **203** as the reaction tube is configured with a double-tube having the inner tube **204** and the outer tube **205** has been described in the above-described embodiments, the present invention is not limited to those embodiments. For example, the process tube **203** as the reaction tube may also be a single-tube.

Although the case of forming the nitride film on the surface of each wafer **200** by supplying high-temperature NO gas (or, mixed gas of N_2O gas and NO gas) into the process chamber **201** has been described in the above-described embodiments, the present invention is not limited to those embodiments. For example, the present invention can also be very suitably applied to a case of forming an oxide film such as BIO, SiO_2 or HTO on the surface of each wafer **200** by supplying oxygen (O) containing gas into the process chamber **201**. Moreover, the present invention can also be very suitably applied to a case of forming films other than the nitride film or the oxide film.

<Complementary Note>

Hereinafter, the preferred embodiments of the present invention will be complementarily described.

In accordance with one aspect of the present invention, there is provided a substrate processing apparatus, comprising: a process chamber configured to accommodate a substrate; a gas supply line configured to supply gas into the process chamber; and an exhaust line configured to exhaust the inside of the process chamber, wherein the gas supply line comprises: a preheating unit configured to preheat the gas before supplying the gas into the process chamber; a metal pipeline configured to supply the preheated gas into the process chamber; and a heat dissipation member covering the outer periphery of a bent section formed in the metal pipeline.

Preferably, the heat dissipation member comprises a pair of metal members between which the outer periphery of the bent section formed in the metal pipeline is intervened by a clamp.

Preferably, the facing surfaces of the pair of the metal members are recessed in the same shape as the bent section in order to increase the contact area between the outer periphery of the bent section and the metal members.

Preferably, at the pair of the metal members, a groove structure is formed to increase the surface area of the pair of the metal members.

Preferably, the gas supply line comprises: a quartz pipeline configured to exhaust the preheated gas out of the preheating unit; and a joint part configured to connect a downstream end of the quartz pipeline to an upstream end of the metal pipeline.

Preferably, the joint part comprises: a first flange installed in the downstream end of the quartz pipeline; and a second flange installed in the upstream end of the metal pipeline, wherein the first flange and the second flange are jointed through a sealing member to face each other, so that the downstream end of the quartz pipeline and the upstream end of the metal pipeline are air-tightly connected together.

Preferably, the inner diameter of the sealing member is greater than the inner diameter of the quartz pipeline and the inner diameter of the metal pipeline, so that high-temperature gas flowing from the quartz pipeline to the metal pipeline does not directly contact the sealing member.

Preferably, at the inside of the second flange, a cooling medium flow channel is formed so that cooling liquid or cooling gas is circulated.

Preferably, the gas supply line comprises a cooling medium exhaust pipe configured to exhaust the cooling liquid or cooling gas from the cooling medium flow channel, and the cooling medium exhaust pipe contacts the heat dissipation member so that heat is transferred to the heat dissipation member.

Preferably, the gas supply line comprises a cooling medium supply pipe configured to supply the cooling liquid or cooling gas into the cooling medium flow channel, and the cooling medium supply pipe contacts the heat dissipation member so that heat is transferred to the heat dissipation member.

Preferably, the cooling medium exhaust pipe is intervened between the pair of the metal members, together with the metal member.

Preferably, a bent section is installed near the downstream end of the quartz pipeline.

What is claimed is:

1. A substrate processing apparatus, comprising:
- a process chamber configured to accommodate a substrate;
- a gas supply line configured to supply a gas to an inside of the process chamber; and
- an exhaust line configured to exhaust the inside of the process chamber,
- wherein the gas supply line comprises:
- a preheating unit preheating the gas supplied from a gas source,
- a metal pipeline having an angled section, the metal pipe line connecting the preheating unit and the inside of the process chamber to supply the gas preheated by the preheating unit into the process chamber, and
- a heat dissipation member covering the angled section to dissipate heat from the angled section,
- the heat dissipation member comprising a pair of metal members facing each other to cover an outer surface of the angled section and a clamping means to fasten the pair of metal members to each other.

2. The apparatus of claim **1**, wherein each of facing surfaces of the pair of metal members includes a recess having a same shape as that of the angled section such that the angled section is disposed within the recess.

3. A substrate processing apparatus, comprising:
- a process chamber configured to accommodate a substrate;
- a gas supply line configured to supply a gas to an inside of the process chamber; and
- an exhaust line configured to exhaust the inside of the process chamber,
- wherein the gas supply line comprises:
- a preheating unit preheating the gas supplied from a gas source,
- a metal pipeline having an angled section, the metal pipe line connecting the preheating unit and the inside of the process chamber to supply the gas preheated by the preheating unit into the process chamber,
- a heat dissipation member covering the angled section to dissipate heat from the angled section,

a quartz pipeline having an upstream end connected to the preheating unit, and

a joint disposed between a downstream end of the quartz pipeline and an upstream end of the metal pipeline.

4. The apparatus of claim **3**, wherein the joint comprises:

a first flange connected to the downstream end of the quartz pipeline; a second flange connected to the upstream end of the metal pipeline; and

a sealing member disposed between the first flange and the second flange.

5. The apparatus of claim **4**, wherein the second flange comprises:

a cooling medium flow channel connected between a cooling medium supply pipe; and

a cooling medium exhaust pipe to circulate a cooling medium within the second flange.

6. The apparatus of claim **5**, wherein one of the cooling medium supply pipe and the cooling medium exhaust pipe is in thermal contact with the heat dissipation member.

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